ARIZONA STATE UNIVERSITY

CEE 593: APPLIED PROJECT REPORT

ALTERNATIVE FUELS IN MUNICIPAL FLEETS

Analysis of Scottsdale’s current fleet and a case for transitioning to natural gas

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BACKGROUND AND OBJECTIVES

Transportation is not only a key component but critical to the mobility and progress of humans and goods in modern society. For cities and municipalities transportation is a key enabler that enables economic development, mobility and movement of goods and services such as transport of solid waste. Nevertheless, given that transportation consumes huge amount of fuel it makes significant environmental, social and economic impacts. Consequently, the choice of fuel for its fleet can have huge impacts due to the sheer scale of operations by both public and private entities at the municipal level. While households and business are shifting to cleaner alternative fuels to address economic and environmental concerns associated with diesel, compressed natural gas (CNG) has also emerged as a prominent choice. Like most alternate fuels, however, CNG vehicles while known to mitigate carbon emissions and provide long term economic benefits and a new supply choice, also come with challenges such as higher capital costs.

The overall objective of this project is to provide a comparative assessment of the impacts of selected fleet operations of the City of Scottsdale. Specifically, the purpose of this report is twofold: 1) to draw a parallel between CNG and diesel vehicles, especially from the perspective of large solid waste trucks, and 2) perform an analysis of Scottsdale's current fleet with an overall goal to make a case for fleet conversion to alternative fuels, primarily CNG and assess potential impacts using the Vehicle and Infrastructure Cash-Flow Evaluation (VICE) 2.0 model developed by the National Renewable Energy Laboratory (NREL). These impacts are quantified using various indicators such as fuel consumption, amortization, capital, demand and labour, which in turn help quantify (un)sustainable measures such as environmental impact, cost per ton and per mile, effect of heavy vehicles on roads, and air quality of cities.

Scottsdale, a prosperous urban city in Arizona, is a leading changemaker and has made great advances in fleet management and the transportation sector. The city is committed to improving transportation as it has a highly diversified portfolio with 276 vehicles running on diesel, 49 on CNG, 11 electric vehicles and the others running on alternative fuels. Most solid waste trucks operate on CNG due to high fuel consumption.

METHODOLOGY AND ANALYSIS

This study adopts a three-step approach in comparing the impact of fuel conversion in the City of Scottsdale's solid waste fleet operations. First, from an economic standpoint, this study compares how large solid waste trucks fare when running on CNG versus diesel engines. It then presents best practice case studies of the cities of Denver and Grand Junction to identify key factors in the implementation of CNG within refuse trucks. Finally, the report analyses Scottsdale's current fleet as well as utilizes NREL's VICE 2.0 model to demonstrate the relationship between project profitability and fleet operating parameters for the city. The sensitivity of payback period towards Rate of Return (ROR) was also calculated.

ECONOMIC ANALYSIS: CNG VERSUS DIESEL COSTS

BUYING COST

Scottsdale has 49 refuse trucks of which 21 are run on diesel while the rest (28) run on CNG. According to three sources (Lemmons, 2009; Andrews, 2009; San Antonio, 2009), the incremental cost of a CNG refuse truck is $30,295 (Johnson, 2010) and therefore an investment of $636,195 would be required to convert the entire fleet into CNG.

OPERATIONAL COST

For both CNG and diesel buses, maintenance and operation costs are considered to be the same because evidence supports both a cost decrease (Chandler et. al 2006) as well as a cost increase (CVEF, 2010) when switching from CNG to diesel. The maintenance cost for a CNG fleet, in 2010, was $1.122/mile versus that of diesel which was $0.072/mile before 2010 (Johnson, 2010). The unclear cost signal portrayed in such studies point to a flux factor due to maintenance learning curves, new diesel emissions equipment, a sub-competitive CNG parts market, and related factors. This cost parity for CNG buses is assumed to apply to CNG refuse trucks as well, which is supported by Engle (2010).

TIMEFRAME FOR CONVERSION

It is vital to gradually phase out diesel vehicles and not convert the entire fleet to CNG simultaneously due to the reasons that follow. Budget constraints need to be accounted for during diesel to CNG conversion due to the high differential cost between the two types of trucks. Also, trucks built in with CNG engines are preferred over conversions as the former have a better ROI over their life compared to the latter which have already been in service for several years. From the perspective of skilled labor, the city might not have trained staff or space to handle new inventory and add decals to vehicles if everything is changed at once. Finally, simultaneous procurement of CNG vehicles would indicate that the lifetime of all fleet vehicles would expire at the same time requiring huge investments at the time of replacement.

MARKET FACTORS

The United States has a significant source of natural gas and a robust distribution system which keeps the prices of CNG low. Historically, CNG fuel prices have been relatively stable and low over several years, while diesel fuel prices have been relatively volatile over several years. This makes CNG fuel more reliable in determining budgetary considerations.

BEST PRACTICE CASE STUDIES

CITY OF DENVER

In the pursuit to lower operating costs, reduce greenhouse gas (GHG) emissions for their fleet and bolster domestic energy sources, Denver performed a research study to explore the feasibility of using alternative fuels such as natural gas, propane, and electricity. By comparing lifecycle operating costs of 1065 vehicles with estimated costs of substitutes, they were able to identify suitable alternative fuels for the 198 different vehicle classes. Some of the metrics used to perform these comparisons were annual fuel savings, incremental costs vs. traditional replacements, payback periods and life cycle savings while making reasonable assumptions about the fuel economy, vehicle costs, and incentive programs.

It is interesting to note that out of all the available options, natural gas due to its high energy content and lower cost per gallon saw the maximum savings. The average annual savings on a vehicle travelling 5500 miles a year amounted to $3500, providing an ROI period of 5 years on the incremental investment. Since CNG vehicles do not have to meet EPA certification requirements like their diesel counterparts, there are avoided costs in emission reduction technologies that are not accounted for in these savings.

However, quite a few trade-offs were identified which can be hurdles in the transition to full-scale adoption of CNG vehicles. The supporting infrastructure such as slow fill or fast fill fuelling stations as well as the costs ranging from $500,000 - $2,000,000 could potentially offset the savings. Therefore, unless there are existing facilities for vehicles that can be transitioned to CNG, the payback looks less than feasible in most cases. Even when facility developers are open to sharing infrastructure, capital cost needs to be incorporated into the fuel cost to recover investments, thereby raising the price of fuel. Finally, CNG vehicles require maintenance bays which need to conform to NFPA standards which are additional costs.

CITY OF GRAND JUNCTION

Grand Junction in an attempt to reduce economic and environmental impacts of its refuse trucks and limit reliance on diesel, decided to investigate the use of CNG for its fleet vehicles. After a bidding process for Operational Equipment Manufacturers (OEM), eight out of the 12 refuse trucks were converted to CNG and a new fast fill fuelling station was built. The decision makers found it fairly simple to make the switch given a number of enabling factors such as increase in the cost of diesel trucks resulted in price differential reduction, lower emissions of CNG trucks, and better energy security.

Through this project, the city realized fuel savings of $10,000 per truck per year and the payback period was estimated to be 10 years to recover both vehicle and station investments. There was only a marginal increase in the maintenance for the new trucks. The station cost $1.3 million and the equipments, installation and building modifications accounted for 85% of this total. Another advantage which is not always necessarily quantified is labour efficiency. The City of Grand Junction also noted a reduction in productive man hours spent on fuelling vehicles and overtime hour.

Despite the overall success of this program, some of the barriers that were identified in the CNG deployment were:

- Disconnect between the impacts of compressor electricity use and on peak charges.
- Refuelling was affected by precision of fuel gauges and inclement weather during the winter months.
- Vehicle availability was highly dependent on the required customization features.
- Significant training needed to be provided to the operators and fleet staff by manufacturers.

CURRENT SCENARIO OF THE CITY OF SCOTTSDALE

The Scottsdale fleet runs on a diverse set of fuels including diesel, B-20 (Bio diesel), CNG, and E85. Scottsdale has also significantly invested in supporting infrastructure around alternative fuels by building fueling stations for all types. Some of the analysis introduced in this section was used as inputs for the VICE 2.0 model. Table 1 presents the portfolio of diesel and CNG refuse trucks of the city.

	DIESEL	CNG
Front Loader	4	4
Side Loader	13	17
Rear Loader	4	7

Table 1. Quantity of solid waste trucks based on vehicle and fuel type

Fuel economy was determined for both vehicle classes. While the diesel vehicles gave a mileage of 2.7 mi/gal on an average, the CNG vehicles averaged 1.5 mi/gal. Appendix A1 provides detailed information of the fuel type, fuel consumption and miles travelled by each of the refuse trucks.

Once the fuel economy was determined, the ROI was calculated based on the average miles travelled per year, differential in price, and fuel cost. For a 27 yard truck, the differential price between a diesel and CNG engine was $36,361 whereas for a 31 yard truck, it was found to be $40,148. Based on the calculations indicated in Appendix A1, the average vehicle miles travelled was 12000. Based on these numbers and fuel prices obtained from the U.S. Energy Information Administration (EIA) Gasoline and Diesel Fuel Update 10, the payback periods were found to be around 6 years for both classes of trucks.

	DIESEL		CNG				
VMT (mi)	Fuel (gal)	Cost ($)	Fuel (gal)	Cost ($)	Differential ($)	Savings ($)	Payback (yrs)
12000	4286	16757	4800	10032	36361	6725	5.41
12000	4286	16757	4800	10032	40148	6725	5.97

Table 2. Payback Period

VICE 2.0 MODEL

Based on the inputs specified in Appendix A2, the incremental cost for Scottsdale was found to be $636,195 to transition all the diesel trucks to CNG. The acquisition of 21 CNG trucks was distributed equally over a period of 3 years as it has been observed during the course of this study that a gradual transition is more beneficial.

RESULTS

Tables 3a and 3b present the results obtained from the VICE 2.0 model. The model returns a net present value of $514,588 for the project with a payback period of around 6 – 7 years. This is in line with the calculations shown earlier in Table 2 and hence bolsters the analysis. Apart from the quick cost recovery, 13,750 tons of GHG will be displaced throughout the project lifetime.

Net Present Value ($)	$514,588
Payback Period (yrs)	6.70
Simple Payback Period (yrs)	5.89

Table 3a. Business Case Results Summary

Displaced Diesel (GGEs)	1,307,768
Displaced Gasoline (GGEs)	0
Total Petroleum Displacement (GGEs)	1,307,768
Project Lifetime GHG Displaced (tons)	13,750

Table 3b. Petroleum and Greenhouse Gas Reduction Summary

Since the payback period is quite sensitive to the ROR which was one of the assumptions within this study, the payback period varies with variations in the ROR as indicated in Table 4.

Rate of Return	Payback
10%	7.46
8%	7.05
6%	6.70
4%	6.40
2%	6.13
0%	5.89

Table 4. Payback sensitivity to ROR

RECOMMENDATIONS

Based on the three-pronged approach of economic analysis, highlights of best practices of two cities, and analysis of City of Scottsdale's fleet operations the following recommendations are suggested:

- The conversion of the entire solid waste fleet to CNG is an economically viable option. However, the transition should be made gradually through attrition instead of buying all new trucks at once.
- Constructing a fast fuelling gas station and sharing the infrastructure with other entities is more viable. It might be a good idea to factor in initial capital investment into the price of the fuel for faster cost recovery.
- Adding CNG retrofits to existing diesel vehicles is not recommended as the lifetime of the vehicle does not improve or change. In fact, the incremental costs are high and the achieved efficiency with the new system on old trucks is not at par with new CNG vehicles.
- Training programs need to be instituted for operators and staff to understand the functioning mechanism and novel features of the new CNG fleet along with effective use of compressor electricity.
- Fuel diversity must be aimed for within the fleet as diversification ensures resiliency towards unforeseeable situations and abrupt market disruptions in both supply and prices.
- Federal tax credits for the use of alternative fuels play a significant role in justifying such projects, and Scottsdale is highly encouraged to apply for related grants or incentive programs to alleviate the burden of initial investments.
- Newer trucks have better fuel efficiency and therefore should be deployed on longer pick up routes and should be covering more areas than the diesel trucks.
- Fleet managers should focus on predictive maintenance, as distinct from preventative maintenance, as frequent idling causes maintenance issues.

In summary, this report closely identifies the best management practice and strategies to transition municipal solid waste fleet to CNG. It provides the City of Scottsdale with lower environmental impact, long term economic benefits, and improved energy security. The recommendations, if implemented, have the potential to allow Scottsdale to move in the direction towards creating and managing an efficient fleet that will enhance the quality of life of its and its neighbouring residents and visitors.

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APPENDIX

A1. The table below presents the fuel type, amount of fuel used, miles driven and the mileage for each of the refuse trucks in Scottsdale's fleet.

Vehicle Code	Fuel FY17 (gal)	Fuel Type	Odometer (mi)	MPG
1005570	5717.7	DIE	14954	2.6
1007579	4846.2	DIE	11230	2.3
1007580	4635.6	DIE	11557	2.5
17528	1226.5	DIE	7900	6.4
1007439	2360.9	DIE	2710	1.1
1010444	7934	DIE	16989	2.1
1012400	9331.5	DIE	9688	1
1012446	7708	DIE	9117	1.2
1012447	8396.8	DIE	15390	1.8
1012448	8567.1	DIE	12906	1.5
1012450	7274.9	DIE	12016	1.7
1012451	8368.6	DIE	13255	1.6
1012452	6918.7	DIE	11779	1.7
1012453	7799.6	DIE	15972	2
18654	1881.8	DIE	7662	4.1
18655	953.1	DIE	7100	7.4
18656	989.1	DIE	6641	6.7
1009477	6226.6	DIE	10926	1.8
1009478	6608.1	DIE	9435	1.4
13173	6561.3	DIE	13524	2.1
16526	8323.2	DIE	Data Not Available	0
1010583	5800.8	CNG	9165	1.6
1010581	5927.4	CNG	7185	1.2
1010582	5138	CNG	8331	1.6
15335	8611.9	CNG	12919	1.5
15336	8671.9	CNG	13808	1.6
16457	8765.9	CNG	12767	1.5
16458	8543	CNG	12799	1.5
1012449	9505.2	CNG	10607	1.1
13196	8699.5	CNG	9336	1.1
13197	10086.3	CNG	15020	1.5
13198	9115.7	CNG	13630	1.5

13199	11549.6	CNG	17651	1.5
15497	10042.1	CNG	14439	1.4
15498	11345.4	CNG	17244	1.5
15499	11440.7	CNG	18054	1.6
15500	11668.3	CNG	17573	1.5
15501	10131.2	CNG	14288	1.4
15411	7524.2	CNG	12104	1.6
15412	9237.1	CNG	12987	1.4
15413	9321.8	CNG	13437	1.4
15414	8474.9	CNG	13129	1.5
15415	7705.1	CNG	13212	1.7
15416	8433.1	CNG	15048	1.8
15417	8196.2	CNG	15044	1.8
13174	8071.3	CNG	9117	1.1
15333	8353.6	CNG	10367	1.2
15334	7978.9	CNG	13368	1.7
15381	8634.7	CNG	11925	1.4

A2. This section defines the various parameters and their corresponding values used as inputs in the VICE 2.0 model. The reader can refer to the analysis spreadsheet in order to access definitions for each of the parameters.

Parameter	Value
Project Type	Vehicle Acquisition
Investment Type	Decoupled
Tax Exemption	Yes
Vehicle Type	Trash truck
Incremental Cost	$30,295
Average VMT	12,000
Average Vehicle Life	12 years
Fuel Economy, Diesel	2.7 miles/gallon
Fuel Economy, CNG	2.4 miles/gallon
Efficiency Difference/Loss	10%
Fuel Pricing & Inflation	U.S. Energy Information Administration (EIA) Gasoline and Diesel Fuel Update 10
CNG and Diesel vehicle maintenance fee	$0.52/mile
Number of vehicles	21
ROR	6%
Vehicle Acquisition	7 (Year 1), 7 (Year 2), 7 (Year 3)